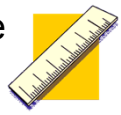
Cells

- Units of life- organisms can be single cells, colonies or multicellular
- Two basic types of cells – prokaryote and eukaryote
- Prokaryote – Bacteria and Archaea
- Eukaryote – Protista, Fungi, Plantae, Animalia

Cell size

- Prokaryote cells mostly 1-10 microns but can be as small as 0.2 microns or as large as 750 microns
- Eukaryote cells mostly 10-100 microns but can be meters long
- Micron = micrometer = 10^{-6} meters =μm

Two ways to compare size



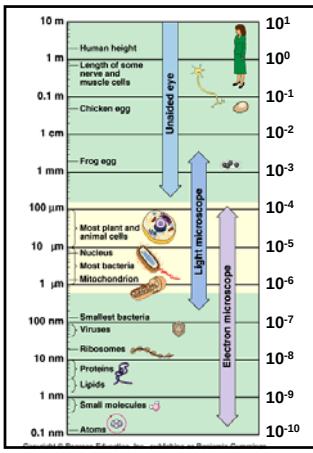
Absolute scale

- increment = fixed amount (e.g. meters)
- useful if range of measurements is small

Relative scale (e.g. logarithmic)

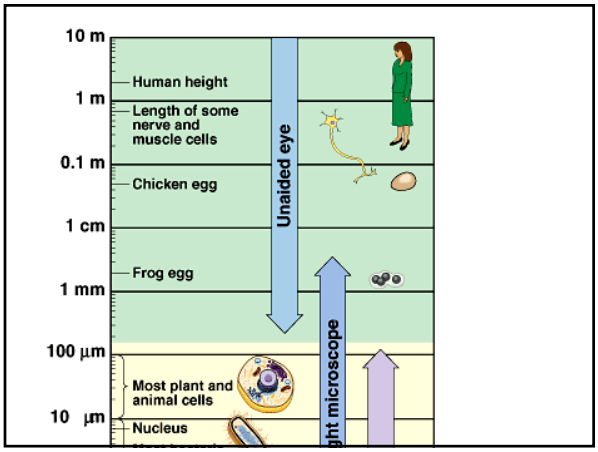
•increment = factor (e.g. multiple of 10)

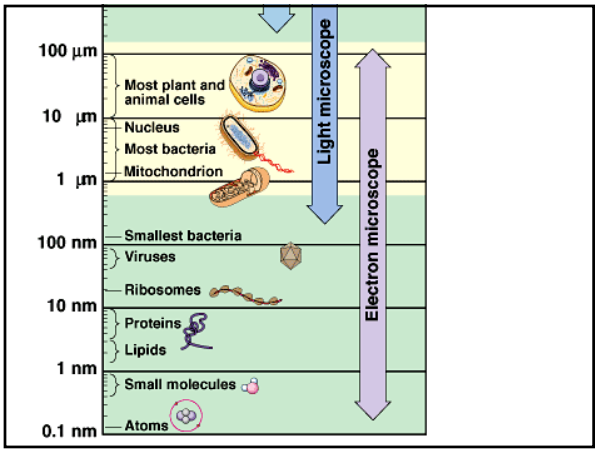
•useful if range of measurements is large



Sizes of objects on a logarithmic scale

- Each unit is 10X larger than the one below it





Relative sizes

- You are ~10^5 times larger than your cells, a relative size difference similar to you compared to something 125 miles long
- You are ~10^9 times larger than your molecules. That is similar to you, compared to 1.25 million miles!

- <http://htwins.net/scale2/scale2.swf?bordercolor=white> **Be sure to go BOTH ways on the sliding scale. Click on any object for a summary.**
- http://ngm.nationalgeographic.com/redwoods/gatefold-image

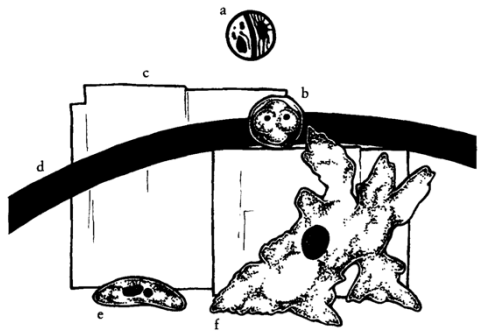


Figure 1.1 One Hundred Times Magnification

a. A collection of cells (enlarged in the next figure). b. Human egg—the largest human cell—at the four-cell stage. c. Grains of table salt. d. Human hair. e. The protozoan *Paramecium multimicronucleatum*. f. The protozoan *Amoeba proteus*.

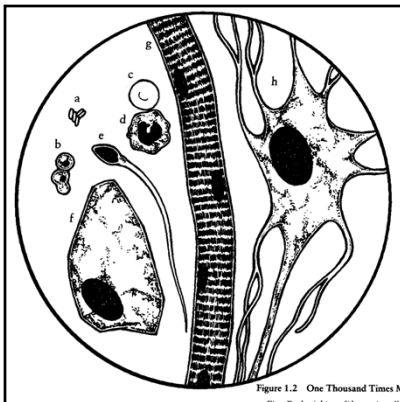
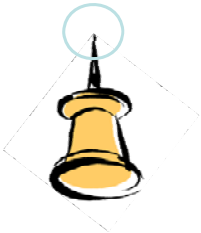


Figure 1.2 One Thousand Times Magnification

a. Five *Escherichia coli* bacteria cells. b. Two cells of baker's yeast, *Saccharomyces cerevisiae*, one in the process of budding. c. Human red blood cell. d. Human lymphocyte. e. Human sperm cell. f. Human epidermal cell. g. Human striated muscle cell. h. Human nerve cell.

E. coli bacteria
~3 μm long

on a pin-point



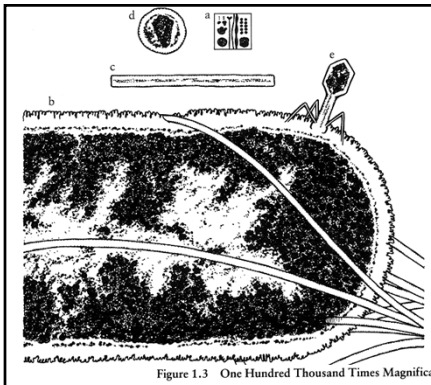


Figure 1.3 One Hundred Thousand Times Magnification

a. A collection of molecules (enlarged in the next figure). b. A bacterial cell (*a* in the previous figure). c. Tobacco mosaic virus. d. Human immunodeficiency virus. e. A bacterial virus.

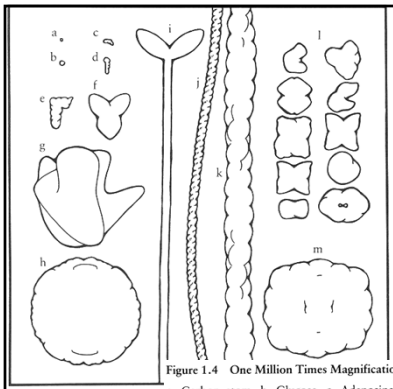


Figure 1.4 One Million Times Magnification

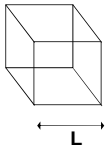
a. Carbon atom. b. Glucose. c. Adenosine triphosphate (ATP). d. Chlorophyll. e. Transfer RNA. f. Antibody. g. Ribosome. h. Poliovirus. i. Myosin. j. Deoxyribonucleic acid (DNA). k. Actin. l. The ten enzymes of glycolysis. m. Pyruvate dehydrogenase complex.

Surface/volume relationship

For any three-dimensional object:

- Surface area is proportional to L^2
- Volume is proportional to L^3
- Therefore, the ratio surface/volume *decreases* as size *increases*.

Example: cube
surface = $6(L^2)$
volume = L^3



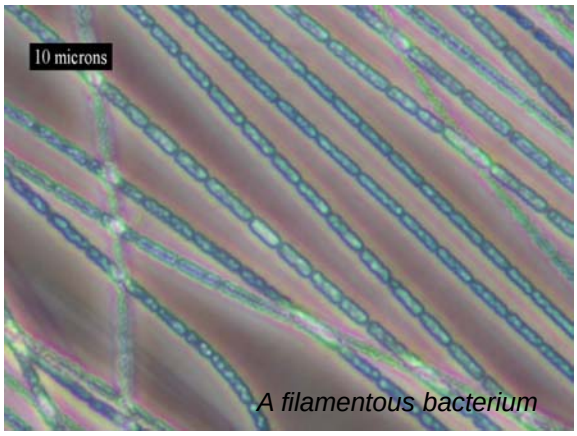
Length	Surface	Volume	S/V
1	6	1	6
10	600	1000	0.6
100	60,000	1,000,000	0.06

Cell size constrained by S / V

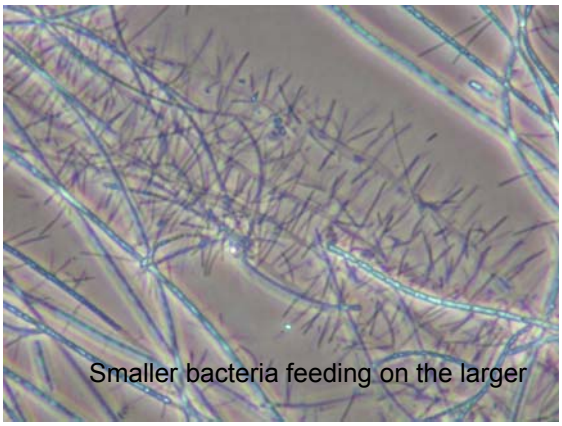
- Surface area limits transport capacity across the cell membrane
- Volume determines the need for transport
- Larger cell has smaller ratio of capacity/need for transport
- Example: respiratory gas exchange of bird & reptile eggs

Proks vs Euks

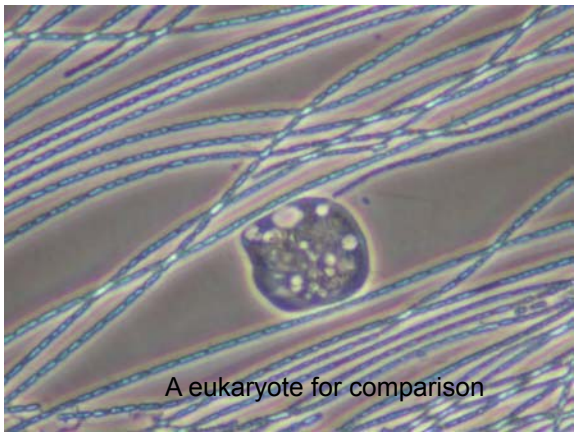
- Prokaryote
  - no internal membranes
  - 70s ribosomes
  - circular DNA and plasmids
  - Cell walls, no endocytosis
- Eukaryote
  - extensive internal membrane systems
  - including membrane-bound nucleus
  - 80s ribosomes
  - linear DNA, histones, chromosomes
  - Most lack cell walls, many have endocytosis



A filamentous bacterium



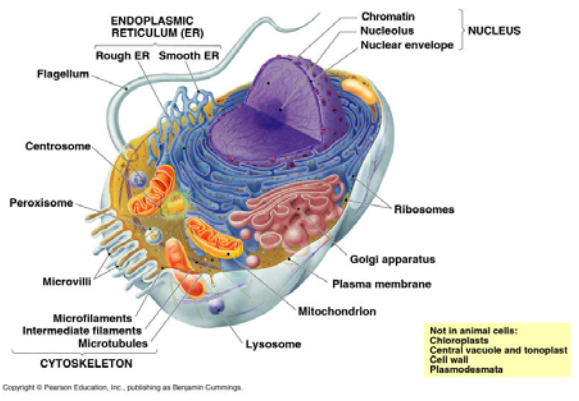
Smaller bacteria feeding on the larger


A eukaryote for comparison

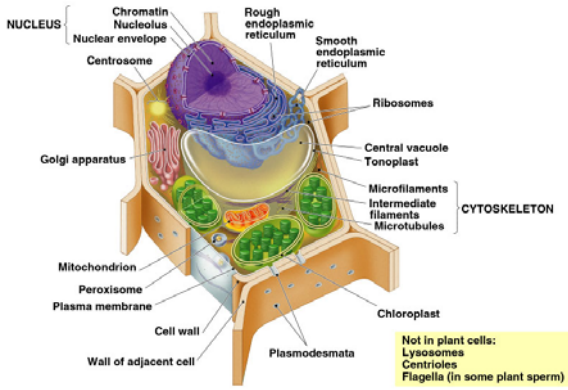
Need to know – eukaryote cell structure

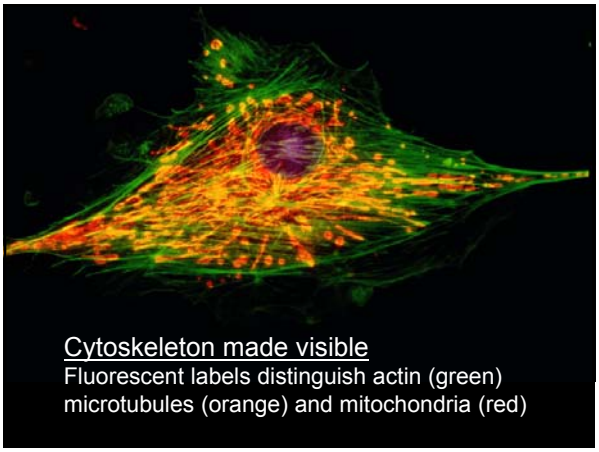
- Learn the names and basic functions of the eukaryote organelles
- Illustrated and described in Figure 4.5 and 4.7 in Brooker.
- I will discuss only a few of these in lecture.

Overview of an animal cell



Overview of a plant cell



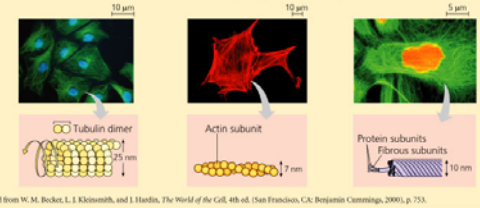


Cytoskeleton made visible

Fluorescent labels distinguish actin (green) microtubules (orange) and mitochondria (red)

Structure and function of cytoskeleton

Property	Microtubules	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina



SOURCE: Adapted from W. M. Becker, L. J. Kleinsmith, and J. Hardin, *The World of the Cell*, 4th ed. (San Francisco, CA: Benjamin Cummings, 2000), p. 753.

Cell motility

- Cytoskeleton elements
- http://www.youtube.com/watch?v=5rqbmLiSkpk
- Fish Keratocytes
- http://www.youtube.com/watch?v=Rq-XOQUW3xU
- Glochidium encapsulation
- Actin motility & *Listeria* bacteria
- http://cmgm.stanford.edu/theriot/researchBasic.htm

Organelles that phosphorylate ATP

Mitochondria

- powered by oxidation of food molecules.

Chloroplast

- powered by light

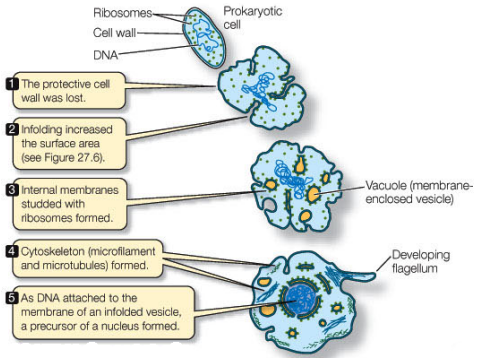
*

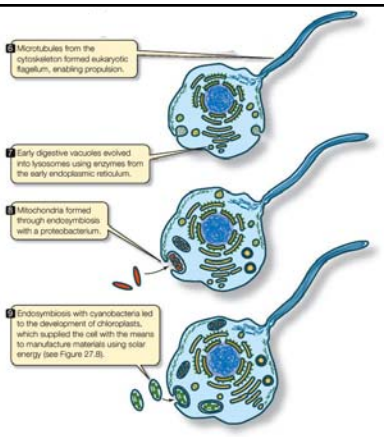
*Cutaway diagrams- Actual shapes vary

Endosymbiotic origin of mitochondria and chloroplasts

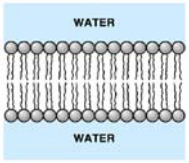
- Similar size to prokaryote cells
- Bounded by double membrane
- Have their own DNA (circular)
- Have their own ribosomes (70s).
- Reproduce by dividing.
- Evolutionary origin as symbiotic partners

Origin of Eukaryotic Cells (see Fig 4.27 Brooker)





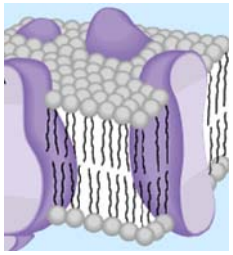
Cell membranes



- Phospholipid bilayer
- Other embedded or attached molecules
  - cholesterol
  - proteins
  - glycoproteins and glycolipids (lipid and protein molecules with oligosaccharides attached)

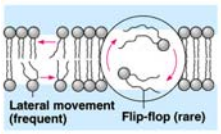
"Fluid mosaic" model

- Fluid because the unanchored molecules can diffuse laterally
- Mosaic because of the embedded proteins

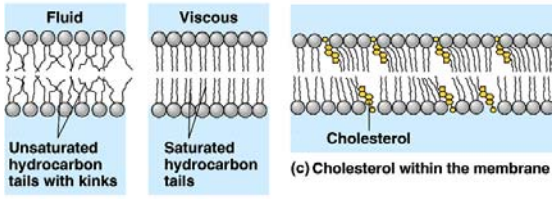


The fluidity of membranes

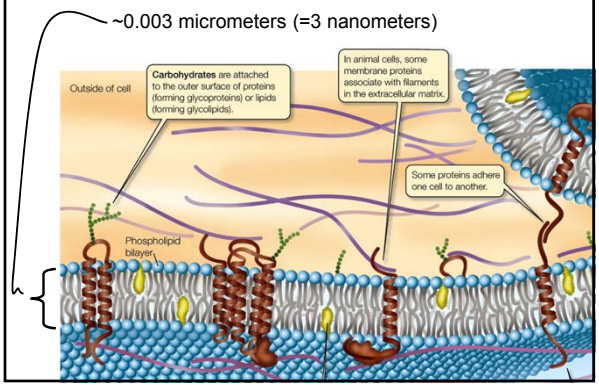
A "liquid crystal" is fluid in 2 dimensions but not 3. The phospholipid molecules can move laterally, but not up or down



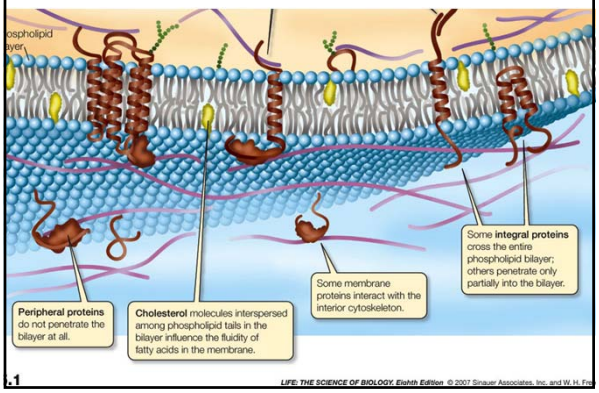
Fluidity is increased by shorter hydrocarbon tails, by unsaturated tails, and by higher cholesterol content



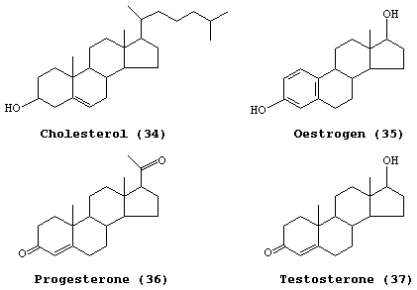
Cell membrane (Chap 5 Brooker)



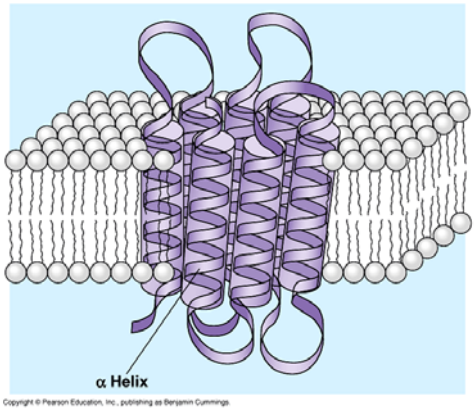
Cell membrane (Fig 5.1)



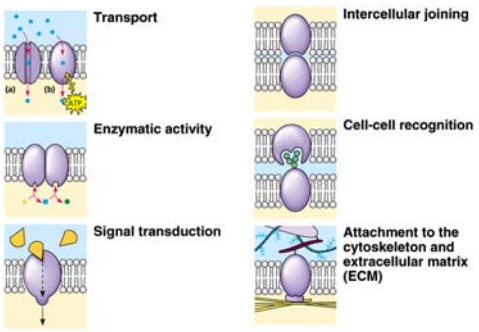
Some representative steroid molecules



The structure of a transmembrane protein



Some functions of membrane proteins



Transport across cell membranes

- Cells are alive- homeostasis requires transport of solutes into and out of the cell.
- Transport of solutes may or may not require energy
- Transport toward higher concentration generally requires energy
- 5 kinds of transport processes:

Spontaneous (passive) transport

- no metabolic energy required
- Diffusion, facilitated diffusion, and osmosis

Energy-requiring transport

- metabolic energy required
- active transport, endocytosis and exocytosis

Diffusion

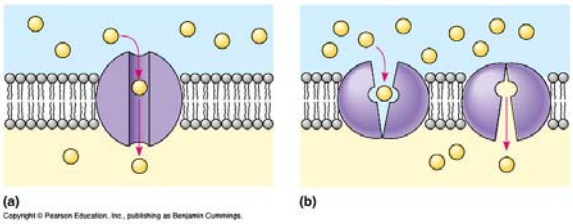
- The spontaneous net movement of molecules toward a region of lower concentration (no energy required)
- The bilayer of the cell membrane is permeable to water, and small un-ionized molecules such as O_2, CO_2
- Not permeable to ions or big molecules

Facilitated diffusion

- Special carrier proteins provide a selective pathway for diffusion of molecules that can't otherwise cross the bilayer.
- the number of carriers controls the rate of diffusion.
- Example- Na^+ channels in neurons

Two carrier mechanisms for facilitated diffusion

Pores Gates



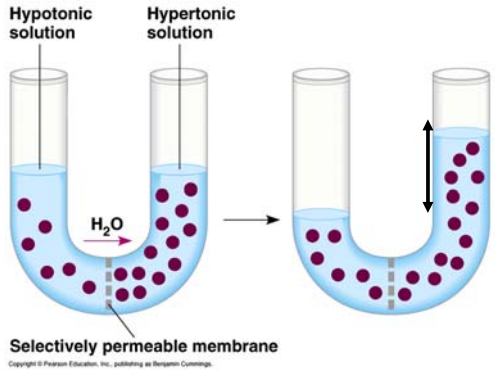
Osmosis

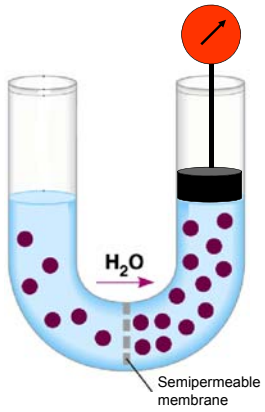
- movement of water toward higher solute concentration (lower water concentration)
- You can think of the solute as “diluting” the water, reducing the concentration of water, causing diffusion.
- In reality, osmosis is not just diffusion- it is much faster- but it’s a useful approximation to call it diffusion

Osmotic pressure

- Pressure that results when two solutions, that differ in osmotic concentration, are separated by a semipermeable membrane.
- Semipermeable (= selectively permeable) water permeates membrane but solute doesn’t

Osmosis





Osmotic pressure

PV = nRT

P = n/V RT

P=pressure
n=number
V=volume
R= gas constant
T= temperature (K)

Same equation used for pressure of a gas

1 Osm → 350 PSI

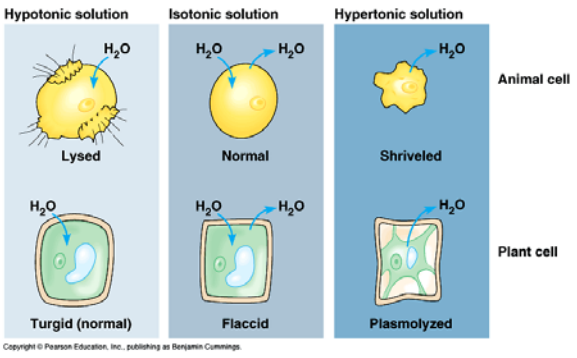
Osmotic concentration

- All solute particles contribute about equally to osmotic concentration
- Osmoles vs Moles
- 1 mM NaCl solution = ~2 mOsm (why?)
- Osmotic refers to concentration
- Tonic refers to pressure

Comparing solutions

- Hypoosmotic/tonic- less concentrated
- Isoosmotic/tonic- same concentration
- Hyperosmotic/tonic- more concentrated
- Why does lettuce wilt in salty salad dressing?
- Why must intravenous solutions be isotonic?
- What about “reverse osmosis”?

The water balance of living cells

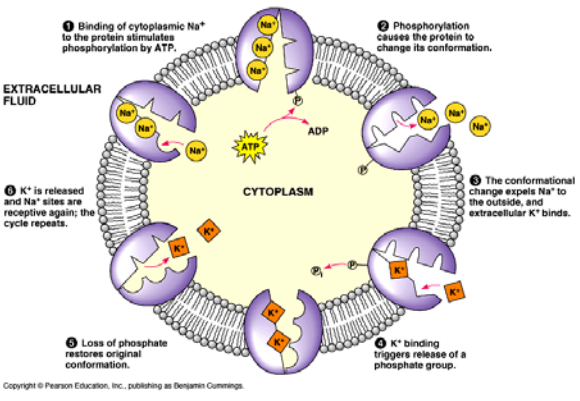


Active transport

- molecular pumps using ATP for power
- Pumps solutes against concentration gradient
- example: Na/K ATPase (sodium/potassium ATPase)

  See Figure 5.14 Sadava, but I like the following diagram better…

The sodium-potassium pump: a specific case of active transport



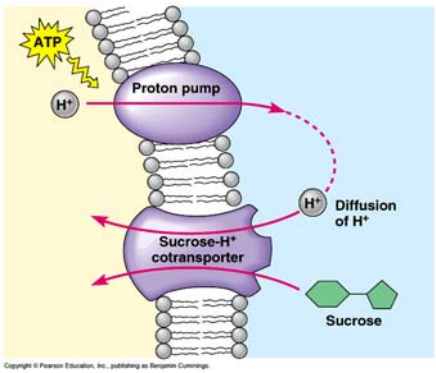
Na/K ATPase

- 3 Na^+ out for each 2 K^+ into cell
- Very important in animal cells- accounts for a large fraction of total energy use
- Diffusion of K+ out and Na+ in is coupled to cotransport of other solutes and other processes
- Electrogenic- creates cell membrane potential – (about -70 millivolts)

Membrane potential is an energy coupling device-

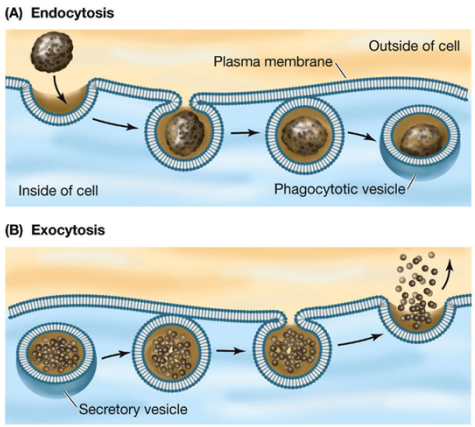
- co-transporters use electrochemical gradient as a source of energy
- Example: H^+/sucrose co-transport
- Hydrogen pumps are used in this way, for example, in the mitochondrion to power ATP phosphorylation

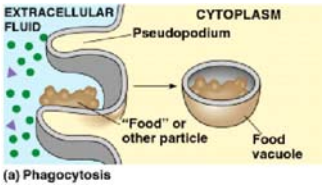
Cotransport (secondary active transport)



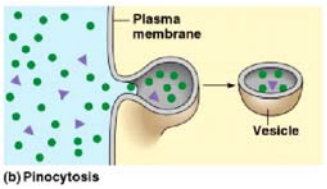
Endocytosis and exocytosis

- Vesicles of membrane carry molecules to the cell membrane and fuse with it
- endo= into the cell, exo = out of the cell
- Phagocytosis
- Pinocytosis
- Receptor-mediated endocytosis

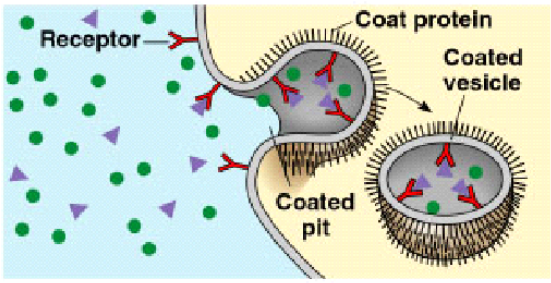




Phagocytosis takes in particles, e.g. smaller cells



Pinocytosis takes in a volume of solution



Receptor-mediated endocytosis

Surface receptor proteins bind specific solutes (ligands) for uptake